§30. Control of the Radial Electric Field Shear by Modification of the Magnetic Field Configuration in LHD

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Control of the radial electric field, E_r, is considered to be important in helical plasmas, because the radial electric field and its shear are expected to reduce neoclassical and anomalous transport, respectively. Although the sign of the radial electric field can be controlled by changing the collisionality, modification of the magnetic field is required to achieve further control of the radial electric field, especially producing a strong radial electric field shear. In the Large Helical Device (LHD) the radial electric field profiles are shown to be controlled by the modification of the magnetic field by 1) changing the radial profile of the helical ripples, ε_h, 2) creating a magnetic island with an external perturbation field coil.

Figure 1 shows the radial profiles of the radial electric field for the ion root (large neoclassical flux with negative E_r in the high collisionality regime), electron root (small neoclassical flux with positive E_r in the low collisionality regime) and the transition regime (between ion root and electron root) for various configurations with different helical ripple profiles. When the helical ripple increases gradually towards the plasma edge (R_{ax}=3.75m, 3.9m), the electron root region extends to half of the plasma minor radius and the radial electric field shear produced is relatively weak. However, when the helical ripple increases sharply at the plasma edge (R_{ax}=3.5m), the electron root region is localized at the plasma edge and strong radial electric field shear is produced. When the magnitude of the helical ripple is suppressed to a low level (R_{ax}=3.6m), the transition region of the radial electric field is located at $\rho = 0.9$, not at the plasma edge, because there is no increase in the helical ripple at the plasma edge in this configuration. These results show that a strong magnetic field shear can be obtained at the plasma edge by shifting the magnetic axis inward rather than shifting the magnetic axis outward, where the achievement of electron root itself is relatively easy (even with higher collisionality). These characteristics are consistent with prediction by neoclassical theory.

Since the plasma flow is expected to be damped inside the magnetic island, a strong radial electric field shear can be produced at the boundary of the magnetic island. Figure 2 show the radial electric field profiles with and without the n/m=1/1 magnetic island, which is produced by external coils. When the perturbation field is applied to the plasma, the radial electric field becomes zero at the magnetic island (R= 4.00m - 4.08m), while it has positive values when there is no magnetic island. Relatively large radial electric field shear is produced at the boundary of the magnetic island. The radial electric field shear at the boundary of the magnetic island becomes more significant when an internal transport barrier is triggered by pellet injection across the magnetic island. When there is no magnetic island, no radial electric field shear and no internal transport barrier are created even with pellet injection. This experiment shows the importance of radial electric field shear appearing at the boundary of the magnetic island in the formation of an internal transport barrier.

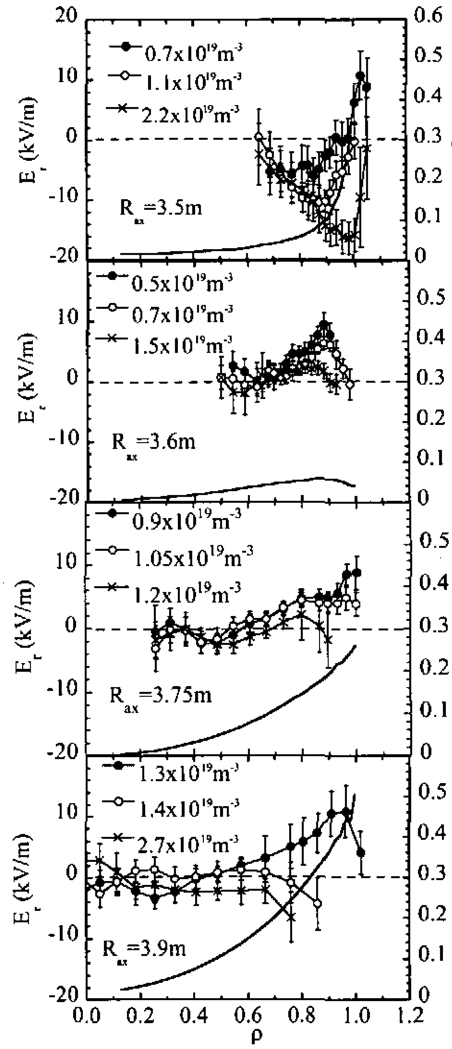

Fig. 1. Radial profiles of radial electric field, E_r and helical ripple ε_h for plasmas with various magnetic axis, R_{ax} of 3.5m, 3.6m, 3.75m, and 3.9m.

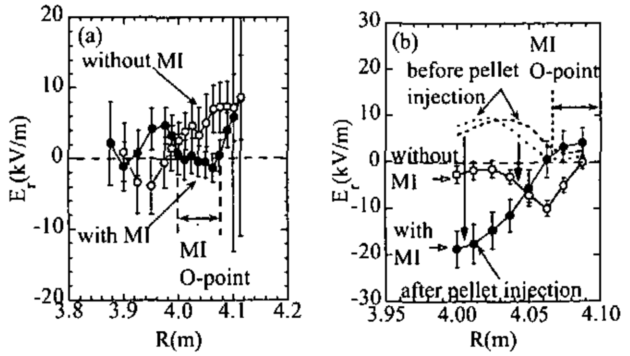

Fig.2. Radial profiles of radial electric field with and without magnetic island (MI) for the plasma (a) in the electron root (b) with pellet injection.